DOE Office of Fossil Energy
Carbon Sequestration R&D Portfolio

Third Annual Conference on Carbon Sequestration

May 6, 2004

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National Energy Technology Laboratory

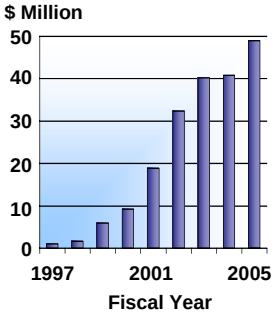
Office of Fossil Energy

Presentation Outline

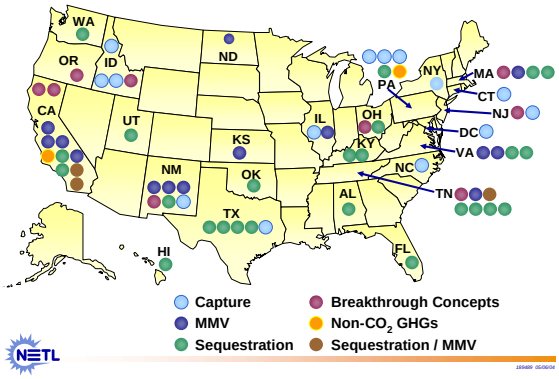
- Project portfolio
- Future opportunities
- Observations

Sequestration: A Dynamic Program

- **Diverse project portfolio**
  - –$140M total value
  - –> 60 projects
  - –BP & IEA consortia
- **Strong support**
  - –Growing DOE budget
  - –36% industry cost share



Sequestration Projects Span Nation

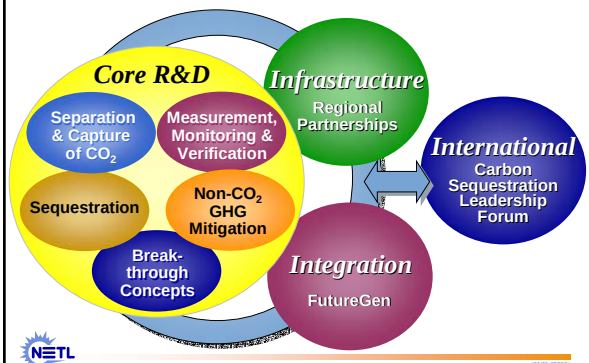


Sequestration Program Goals

By 2012

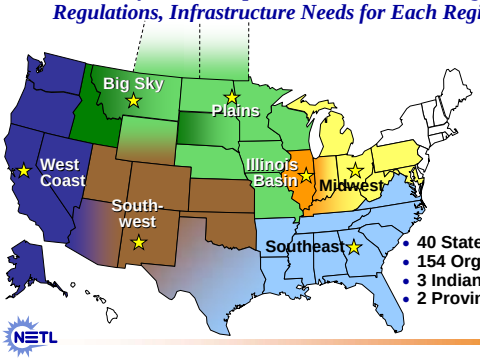
- Provide commercially ready options that meet cost goals
- Establish measurement, monitoring & verification protocols
- Contribute to Administration's goal of reducing GHG intensity by 18%

U.S. DOE/ Fossil Energy Program Organization



Seven Regional Partnerships

Network of Partnerships to Determine Technologies, Regulations, Infrastructure Needs for Each Region



- 40 States
- 154 Organizations
- 3 Indian Nations
- 2 Provinces

FutureGen

Sequestration & Hydrogen Research Plant

" . . . the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant . . . "

February 27, 2003

Carbon Sequestration Leadership Forum

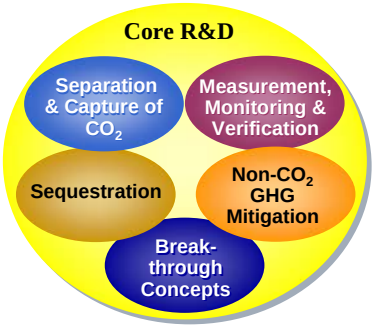
International Climate Change Initiative

- **Facilitate development of cost-effective technologies**
- **Promote technical, political, and regulatory environments to develop such technology**

Charter Signing Ceremony, June 2003, Washington, D.C.

www.cslforum.org

Elements of Core R&D



Separation & Capture of CO_2

Issue

- **Demonstrated technology is costly**

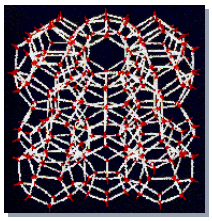
Pathways

- **Pre-combustion capture**
- **Post-combustion capture**
- **Oxygen-fired combustion**
  - Chemical looping
- **Optimized engineering**

CO_2 Hydrates Technology

Pre-Combustion Capture

- **Removes CO_2 from shifted synthesis gas by forming a hydrate slurry**
- **Produces a high pressure CO_2 stream**
- **Preliminary economics promising**



CO_2 Hydrate Clathrate Structure

Participants: Nexant, SIMTECHE, LANL

SRS Daresbury Laboratory (UK) Annual Report 1994-1995

Measurement, Monitoring & Verification

Issue

- Proving CO_2 fate

Pathways

- Surface and subsurface CO_2 leak detection and mitigation tools
- Atmospheric detection systems
- CO_2 fate and transport studies
- Protocols for accounting and permanence

Digital Aerial Imagery to Estimate Carbon Stocks in Above-Ground Vegetation

Soil-Carbon Scanning System

- Rapid measurements of below ground carbon without disturbing soil
- Scan large areas
- Determine changes in soil-carbon with time

Components of Future Field Measurement System

Participant: BNL

Sequestration R&D

Issues

- Health, safety, and environmental risks
- Uncertain regulatory framework
- Site selection

Pathways

- Field experiments / demos
- Protocols for identifying amenable storage sites
- Capacity evaluation studies
- Underlying science

Frio Brine Field Sequestration Experiment

- Drill 5,000-foot well
- Inject 3,000 tons CO_2
- Extensively monitor
- Investigate safety, capacity, permanence

Participants:

- *U. Texas Austin BEG*
- *Texas American Resources*
- *BP America*
- *Schlumberger*
- *Sandia*
- *LBNL*
- *LLNL*
- *ORNL*

Non-CO_2 Greenhouse Gas Mitigation

Issue

- Methane a powerful GHG

Pathways

- **Technologies to mitigate large fugitive releases**
  - Coalbeds
  - Landfill gas
- **Collaboration with EPA on best-practice mitigation options**

Yolo County Bioreactor Landfill

- Accelerated landfill biodegradation
- Methane recovered for power production or other use

Filling Bioreactor Landfill

Participants:

- *Yolo County (CA)*
- *Solid Waste Assoc. of N.A.*
- *Inst. of Envir. Management*
- *U. of Delaware*

Breakthrough Concepts

Issue

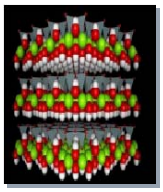
- Need revolutionary approaches to meet DOE cost goals

Pathways

- CO_2 conversion to benign, solid forms
- Advanced capture concepts
- Biogeochemical processes

CO_2 Mineralization

- CO_2 can react with minerals to form stable, solid carbonates
  - In plant
  - In-situ
  - Remediation strategy



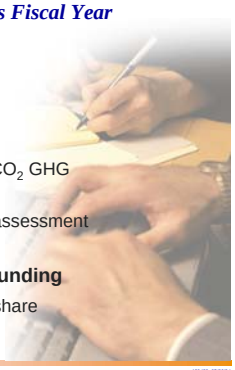
Atomic Surpentine Structure

Participants: Albany, ASU, LANL, SAIC

Broad Agency Announcement

Anticipate Issuing this Fiscal Year

- Four areas of interest
  - Direct capture technologies
  - Indirect capture technologies
  - Technologies for mitigating non-CO_2 GHG emissions
  - Monitoring, verification, and risk assessment for carbon sequestration
- Anticipate $1M FY 05 Federal funding
  - 20% minimum non-Federal cost share



Phase II of Regional Partnerships

Details Still Under Development!

Tasks

- Establish and implement
  - Measurement, monitoring & verification protocols
  - Accounting, regulatory & liability action plans
- Implement outreach mechanisms
- Perform proof-of-concept field tests for technology & infrastructure concepts

The Plans

- $3-5 M/year for each of five regions
- 20% cost share requirement
- Open to all completing equivalent of Phase I

Not a technology development program!

Observation I

The Sequestration Program Is A Serious Effort

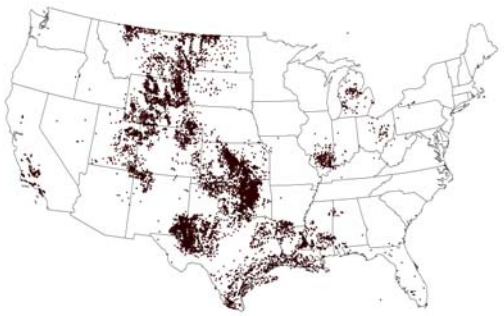
A Serious Effort . . .

- Representatives from industry, environmental community, labs, regulators, high-level government engaged
- International in scope
- Significant government and industry investment
- Multitude of projects underway
- Discussions on CO_2 credit trading, regulatory structure, liability

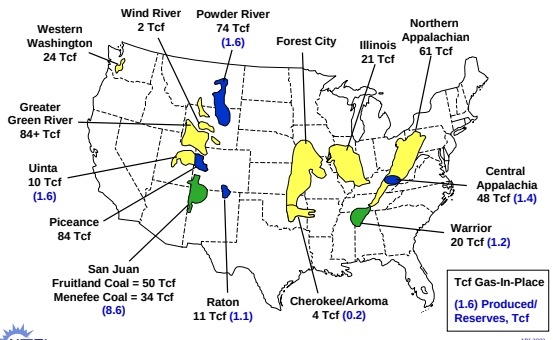
Observation II

Our Understanding of Sequestration Geology, Mechanisms, Capacity Is Improving

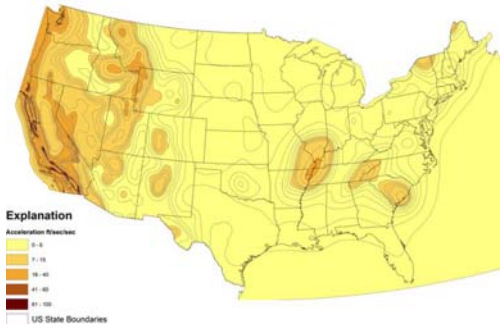
Brine Well Locations



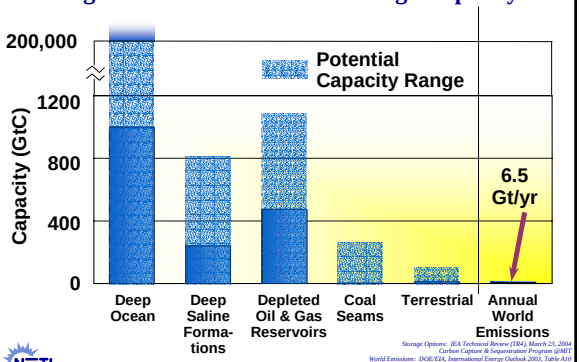
Coalbed Methane Deposits



Seismic Potential



Large Potential Worldwide Storage Capacity



Observation III

Our Understanding of the Cost of Sequestration Is Improving

Percent Increase in COE Due to CO2 Capture

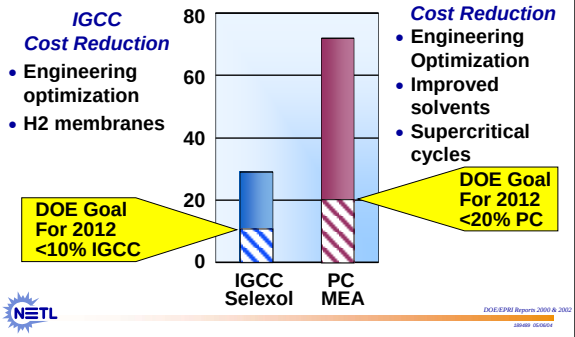
Greenfield Plants, Circa 2000

IGCC Cost Reduction

- Engineering optimization
- H2 membranes

PC Cost Reduction

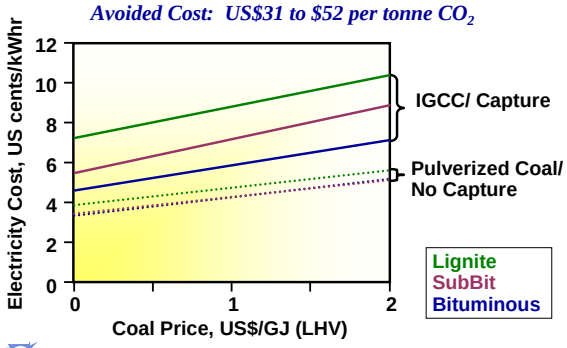
- Engineering Optimization
- Improved solvents
- Supercritical cycles



DOE/EPRI Reports 2000 & 2002

Sequestration Costs in Greenfield Plants

Avoided Cost: US$31 to $52 per tonne CO_2

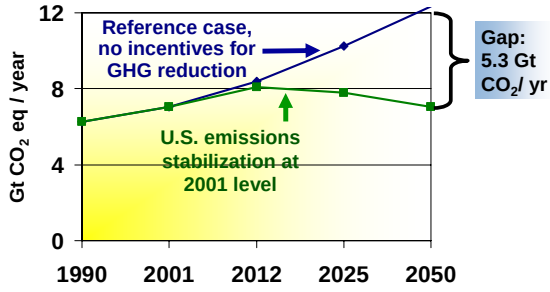


IEA Greenhouse Gas R&D Programme summary of Canadian Clean Power Coalition (CCPC).

Observation IV

Increased Discussion of Inclusive Pathway to Emission Stabilization

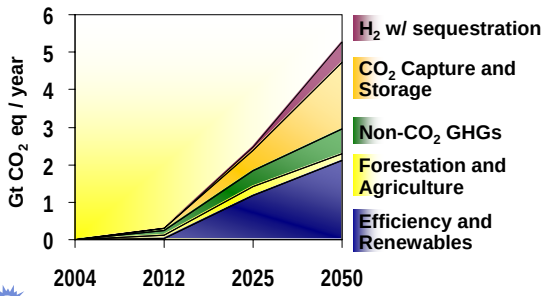
Two Scenarios for U.S. GHG Emissions



NETL/ARIEnergetics 2004

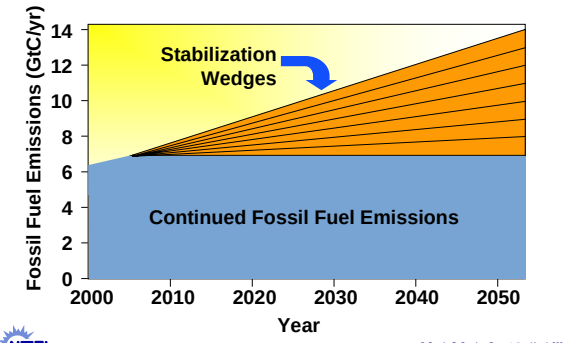
Sequestration Enables Stabilization

Could Account For > 60% of "Gap" in 2050



DOE/FE/NETL Analysis 2004

Professor Socolow's Stabilization "Wedges"



S. Pacala, R. Socolow, Presentation, May 4, 2004

Observation V

Improved Framing of Our Experience with Sequestration Analogues Could Facilitate Public Acceptance

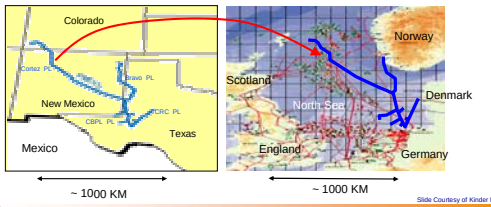
Active U.S. Waste CO_2 EOR Projects

State	Plant Name(s)	Plant Type	CO2 Supply (MMcfd)	EOR Fields	Operator
Texas	Mitchell, Gray Ranch, Puckett, Terrell	Gas Processing	250	SCCROC Crossett	Pennzoil, Altura
Colorado	LaBarge	Gas Processing	150	Rangely	Chevron
Oklahoma	Endid	Fertilizer	35	Purdy	Occidental
Louisiana	Koch	Gas Processing	25	Paradise	Texaco
Total			460		

Source: Barriers to Overcome in Implementation of CO2 Capture and Storage (1) Storage in Disused Oil and Gas Fields, IEA Report PH3/22, February 2000.

Kinder Morgan CO_2 Pipeline System

- Cortez, Central Basin, Canyon Reef Carriers Pipelines
- Similar in size to pipeline between Denmark / North Sea
- Compressor stations pump stations, pressure reducing stations, meter stations, two control centers
- Operations began in 1972



Slide Courtesy of Kinder Morgan

Observation VI

We've Come a Long Way!

Themes at Annual Review Meetings

1998-2001	Program justification
2002	Problem identification, Round 1
2003	Project initiation
2004	Project results Problem identification, Round 2
2005	Information synthesis Outreach status

Successful Technologies To Sequester Carbon Will

- Be effective and cost competitive
- Provide stable long term storage
- Be environmentally benign
- Be acceptable to the public